Designing an Interactive Mobile Assessment Tool to Quantify Impact of the Environment on Wellbeing

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Abstract. The ubiquity of mobile sensing and smartphone capabilities offer a significant opportunity to obtain real-world sensor data and momentary mental wellbeing fused at the point of exposure. In this paper, we present the design, implementation and evaluation and user experiences of Urban Wellbeing; a cross-platform mobile application, which aids in quantifying the relationship of the environment, behaviour and mental wellbeing. Urban wellbeing integrates: (i) real-time environmental sensor data in the form of Air Quality Index, (ii) momentary mental wellbeing assessment in the form of emojis, (iii) image and the type of environment and (iv) noise levels in decibels. We report early findings from trials conducted based on the design of Urban Wellbeing to promote engagement. Our preliminary results of Urban Wellbeing, tested with both iOS and Android smartphones demonstrate that it can be effective as a personal environmental and wellbeing sensing application and engaging for users.

Keywords: Urban Wellbeing · Environment · Mental Wellbeing · Air Quality · Ecological Momentary Assessment

1 Introduction

A significant impact of the growth in the world, particularly environmental factors (such as Particulate Matter 2.5, noise, and gases) within the environment are having a significant impact on our health [18], [17], behaviour [10] and mental wellbeing [14]. As the population increases and our urban environments obtain more focus it is expected that 66% of the global population will live in urban areas by 2050 [11].

Recently, a World Health Organisation study found that 91% of the world's population is living in areas where air quality guidelines are not met which is resulting in over 4.2 million deaths each year [2]. In addition, many places across the UK where these guidelines are not being followed is resulting in more serious health conditions such as higher heart rate leading to heart disease and asthma [2], or even death [17].

The use of sensor-based technologies and mobile sensing devices have the greatest opportunity of understanding the impact of exposures within a range of urban environments as well as quantifying the impact to individuals through assessment-based questionnaires [15], [13]. Smartphone momentary wellbeing assessments using environmental factors is lacking with limited contribution of using objective sensor data. Specifically, previous research has only explored these using questionnaires with limited user interaction and data obtained from real-world sensors [3].

In this paper, we propose, discuss the design and explore the implementation of our environmental and wellbeing sensing system tool *Urban Wellbeing*, that is able to unobtrusively fuse wellbeing states and objective sensor data in the form of environmental factors such as air quality, noise and gain a perspective on the environment through image and location. Urban Wellbeing is an application that aims to bring us closer to understand the impact of urban environments on mental wellbeing as an interactive assessment tool

The rest of this work is organised as followed: Section 2 describes the background and related literature review. Session 3 discussed the system design, including the process participants complete to carry out an assessment. Section 4 shares the results from a set of users who have tested the design of Urban Wellbeing. Finally, section 5 considers the conclusions drawn from this work and work to be considered in the future.

2 Background/ Literature Review

As individuals, within each urban environment, we are exposed to a range of stressors, such as particulates, noise and gases which have been shown to result in a negative impact on our health [20], behaviour, physiology [16] and mental wellbeing [14]. The impact of our environment is largely dependent on the time, location and type we are in to experience the exposure. There has been considerable research attention to the impact of poor air quality within the environment particularly towards health related issues, however, there are still considerable opportunities to explore the impact on mental wellbeing. Recently a study found that mental wellbeing illnesses are steeply increasing and expected to cost the UK economy over £2 billion each year [21].

Across many studies, the combination of mobile technologies and sensors are becoming increasingly popular approaches to provide a greater insight into the impact of the environment direct at the point of exposure. This research opportunity highlights the potential of utilising technological resources whereby exposure to the environment can be accurately assessed and calculated [23].

Sensor fusion approaches have been shown to be effective when investigating the relationship between the environment, physiology, behaviour and wellbeing, including our own work. In particular, the DigitalExposome concepts can bring us closer to unravelling the impact of the environment on wellbeing, highlighting that particulate matter correlates with ElectroDermal Activity (EDA), Heart-Rate Variability (HRV) and results in a worsened wellbeing state when exposed

to a high level. Additionally, using the concept of semantic trajectories using episodes has shown a worsened wellbeing can be caused by a polluted urban environment [12].

ExpoApp utilised a similar approach to study the short-term health impacts of high air pollution with the result demonstrating those who weren't able to access green spaces inhaled higher rates of air pollution [7]. Furthermore, 'Project HELIX' investigated the environmental impact on individuals living in urban environments demonstrating increased level of blood pressure, allergy and asthma illnesses for those who particularly living in urban environments [19].

An ecological momentary assessment (EMAs) involves capturing people's thoughts and behaviours at the moment of exposure repeatedly within an environment [1], [22]. The use of EMAs has been shown to be extremely popular within studies conducted to obtain a human perspective on wellbeing and the environment. A study in 2018 explored the use of EMAs as the context for collecting wellbeing, demonstrating that exposure to nature and daylight correlated with a better affective state [4].

Until recently, EMAs were carried out with as 'pen and paper' approach, which was effective in being able to assess wellbeing [24]. A significant growth and development of mobile technologies and their capabilities enables EMAs to be incorporated for a more portable assessment at the time of exposure. As such, a previous mobile application, *Urban Mind* [3] has used a smartphone mobile application approach to assess the environment through a series of questions based on an ecological momentary assessment. This approach demonstrates a good knowledge gained from EMAs into the natural features of the environment and the direct impact to wellbeing. In summary, the use of smartphones for momentary wellbeing assessment is lacking in terms of using objective sensor data which is linked to the exposure directly at the exact location.

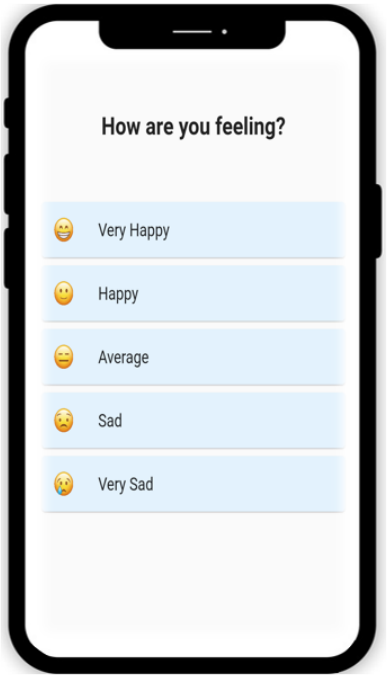
3 System Design: Urban Wellbeing

To overcome the limitations of existing literature, we propose the design of *Urban Wellbeing* as a cross-platform (iOS and Android) interactive assessment tool that aids in supporting the work of unravelling the relationship between the environment and mental wellbeing. The mobile application encompasses a range of data collection types including: live sensor data from the Department of Environment, Food and Rural Affairs' Automatic Urban Rural Network (DEFRA AURN), image of current environment, momentary mental wellbeing (recorded using emojis), timestamp and location as identified at Figure 1. The overall aim of *Urban Wellbeing* is to complete the assessment individually and as much as possible whilst going about your day or to carry this out in a different locations. This research has been approved by Nottingham Trent University Ethical Committee (application number 648). At the start of each assessment, participants must agree to carry out the study and are informed of their options, should they wish to withdraw from the study.

Fig. 1. The individual data types that are involved in the Urban Wellbeing assessment process. These involve: Air Quality data from live sensors, exact location, image of current environment, personal noise level, wellbeing labelled using emojis and timestamp of assessment event

3.1 Real-time Wellbeing assessment

To complete the assessment within *Urban Wellbeing*, users are required to record their wellbeing using five well-known emojis and text-equivalent meanings displayed on buttons as depicted at Figure 2. The table also at Figure 2 shows how wellbeing is calculated in terms of assigning an individual score to each emoji, from *1=negative/low* to *5=positive/high* . The 'Personal Index for Adults' self-assessment of measured satisfaction has been adopted to ask users how they are feeling with their life as a whole [6]. We have adapted this into the form of a five-point Likert SAM scale [5], to provide a proven method for self-reporting subjective wellbeing. There have been several studies that utilise this approach, including our own work [12], [13] which has shown how momentary wellbeing can be effectively obtained, such as DigitalExposome [14], NeuroPlace [16].



Emoji	Wellbeing Score
😁	5 – Very Positive
🙂	4 – Positive
😑	3 - Neutral
😟	2 - Negative
😢	1 – Very Negative

Fig. 2. Urban Wellbeing assessment of wellbeing using emojis and table showing equivalent scoring compared to emojis

3.2 Environmental Image Capture

To gain an understanding into what the environment visually looks like when the assessment is taking place, participants are invited to capture an image using the in-build camera of the wider environment they are currently standing within. Depicted at Figure 3 demonstrates this page in action, along with the image consent which participants must 'agree to understand' prior to being able to take the image. Whilst testing the Urban Wellbeing application, four images at Figure 3 show examples of what was collected from several participants.

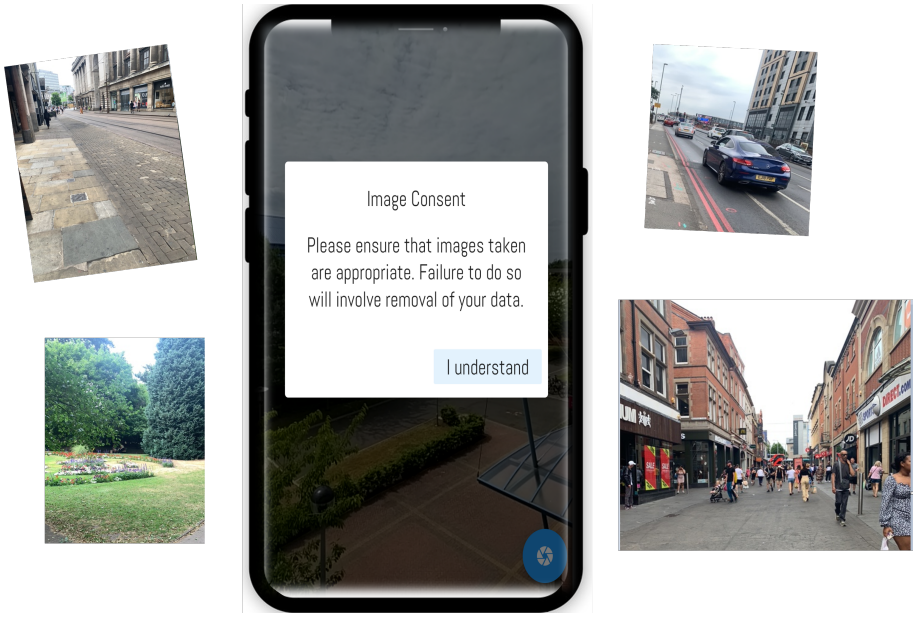


Fig. 3. Urban Wellbeing image capture along with 4 example images taken

3.3 Environment Air Quality and Noise

The final process for the assessment is to collect the environmental levels of air quality and noise which is relative to the participants' specific location. On clicking 'Capture' as depicted at Figure 4, a loading bar will form around the noise icon which results in several processes of obtaining the participant's location, Air quality and noise level.

We gather air quality readings by using data collected by the DEFRA AURN stations [8] which are positioned across the United Kingdom. In particular, the data obtained includes: Real-time Air Quality Index, Air Quality Level and AURN station ID. The Air Quality Index is a process of combining all of the

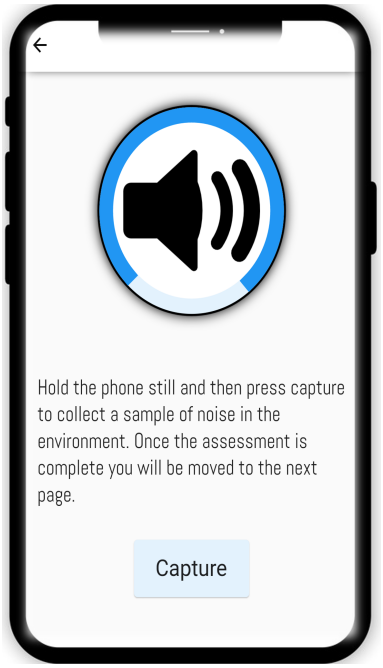


Fig. 4. Urban Wellbeing air quality and noise sampling

individual pollutants collected at each AURN station either taking the highest recorded value or averaging out the values across a period of time [9]. Secondly, noise is obtained from the assessment which is calculated by recording a series of noise clips in decibels which are collected over a period of 5 seconds. Finally, at this point all the data has been saved locally stored on the phone and with the timestamp (DD/MM/YYYY) added, the combined data is sent to a secure database ready for analysis. To protect users and in-line with ethics agreement, no data is stored in the database to identify a participant.

4 Results

A preliminary study has taken place to evaluate the design of the application and performance as a tool to capture live environment sensor data and wellbeing, to aid in quantifying the relationship between the two variables. In total, 5 participants were recruited for testing of Urban Wellbeing and interviewed following a full day of utilising the application in the wild. There was an equal download of Urban Wellbeing made up of iOS and Android platform between the participants.

When interviewed after using the Urban Wellbeing app for the day, it was found that the majority (4) participants informed us that they enjoyed using the mobile application to understand how the environment could play a part

in their wellbeing. Overall, these participants were able to use Urban Wellbeing and complete the assessment process several times throughout their day. One participant struggled with the concept and process through the application and what they had to do. Some of the participants at times reported that the final screen (Figure 4) was a little slow at loading causing some issues with waiting around for the assessment to be completed.

Another concern was that one participant hadn't clicked on the 'accept permissions' when prompted so therefore the application was not able to be used. All participants agreed that there should be some sort of incentive to carry out the experiment using the mobile application, with one stating perhaps a series of badges per environment or step counter activity.

Following discussions with all participants after their day, it was mentioned that a loading screen before the assessment starts should be presented which briefly explains the main ideas and understanding of the work to be carried out. As such, a landing page has been developed into the application with three separate pages detailing the app itself, the walk outline and how the results of this study will be used, as depicted at Figure 5.

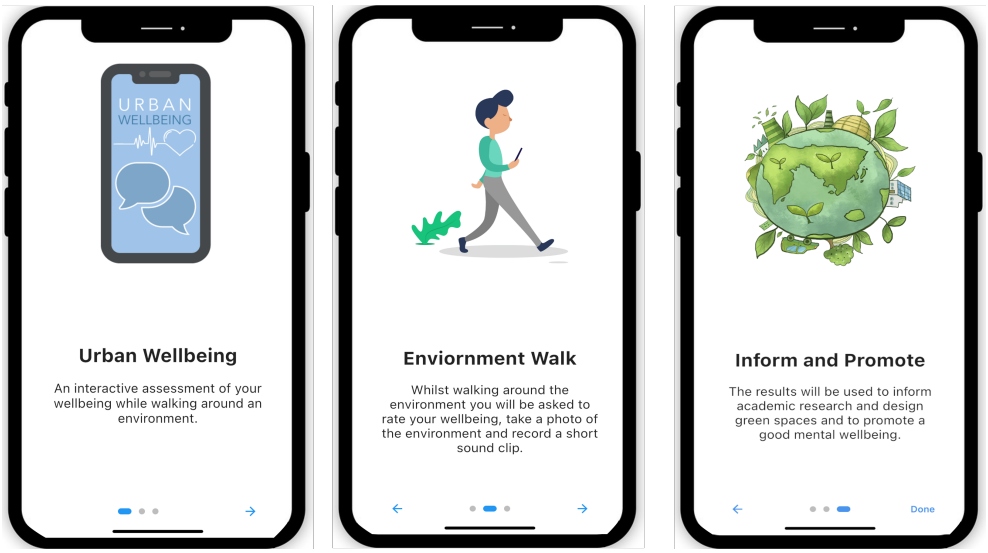


Fig. 5. Urban Wellbeing mobile application three landing screens to give a general overview of the application before starting the individual assessment

5 Conclusion and Future Work

The use of smartphones combining a ecological assessment tool and live sensor data has helped to develop a novel environmental assessment tool with fusing data at the source of exposure that demonstrates the potential to quantify the relationship between urban environmental factors and mental wellbeing. Individual assessments made up of (i) self-labelled wellbeing, (ii) environment image capture, (iii) air quality and noise collection shows the capabilities of understanding the changes within the environment at a more direct perspective, logging at the point-of-exposure. The preliminary trial involved five participants who tested the applications design whilst in a real-world environment and demonstrated the potential for the app to be used alongside daily life and to gain a closer understanding into how certain environmental factors can have a direct impact on their wellbeing.

In the future, a larger trial will be conducted with more participants to further demonstrate the impact not only of the Urban Wellbeing mobile application but the relationship between the environment and mental wellbeing, as well as to gather additional user feedback. There is further work that could be investigated such as an incentive to use the application to collect more reliable data. We envision future versions of the application could be used to notify users where they recently labelled their wellbeing as negative as a place to avoid and for urban planners to encourage the design of urban spaces.

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